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Original Paper

Applying the Life Cycle Analysis in the Construction of Social Housing in Cameroon: The Case of Single-Store Houses at the Sic Residential Area in Olembe (Yaounde)

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Abstract

This study proposes an analysis approach of the life-cycle of two types of social housing of "T4 single-storey houses". This is to determine which phase of the life-cycle calls for special attention in the process of reducing the impact of this sector on the environment. In order to successfully carry out this task, we first carried out a general review of the LCA as a decision-making guiding tool. Then, we alluded to social housing projects in Cameroon as the implementation framework of our guiding tool. Finally, after updating the database of some components of the building sector, we proceeded to the implementation on our two samples. Results obtained high light the importance of the exploitation phase. More interestingly, considering all twelve environmental impact indicators taken into account, the utilization phase that involves exploitation and maintenance is more predominant, causing 82 to 86% of the total impact, followed by the construction phase with 13 to 18%, and then by the demolition phase with 0.01 to 1%. As concerns the economic aspect, the utilization phase remains the most preoccupying. It represents at least 65% of the overall cost of the life cycle, followed by the construction phase and demolition phase.

Keywords

life cycle analysis, social housing, sustainable development, environmental impact

1. Introduction

The housing crisis that has been plaguing Cameroon for close to twenty years has prompted the State to launch social housing projects in various cities of the country. That is why a pilot program for the construction of 10.000 low-cost houses was initiated in the two major cities of Cameroon, that is Yaoundé, the political capital at the Olembéneighborhood (at the northern entrance of the city) and in Douala, the economic capital, in the Mbanga-Bakoko area. However, it is well-known that the civil engineering works in general, and construction of houses in particular, transform and severely damage the environment. As matter off act, the construction activity requires the massive use of natural renewable or non-renewable raw materials. This also implies the production of important quantities of inert wastes and the emission of pollutants such as carbon dioxide, fine particles, and volatile organic compounds. That is why it is imperative to integrate the environmental preservation aspect in the management of projects of such magnitude, because for too many years, the emphasis was mainly laid on the cost of activities, leaving aside the analys is of impacts made on the environment. Thus, in order to render buildings more ecological, it is important to know the various phases of their life cycle. We should also be able to determine the most important phase interms of environment a impacts and avoid shifting pollution from one phase to the other. In order to fill this need and have an integral view of the issue, the Life Cycle Analys is appears to be the appropriate tool. It is in this light that this paper was drafted with the objective of applying the life cycle analys is to a "T4 one-storey" low-cost house in the urban area of the center Region. We shall present the LCA tool, the various phases of the life cycle of a building and determine the most toxic phase in terms of environmental impacts. A better knowledge of the impacts as sociated to products helps to seta order of priorities for improving and informing organizational and technical options.

1.1 Life Cycle Analysis

The Life Cycle Analysis (LCA), that was developed in the sixties, is used to quantify the impacts of a "product" (good, service or process), from the collection of its constitutive raw materials up to their destruction, through their distribution and use ("from the cradle to the grave" analysis). The flow of raw materials and energies involved and produced teach step of the life cycle relisted, and an exhaustive account is made of the consumption of energy, natural resources and polluting emissions in the environment (air, water and soils). The ISO14040 standard describes the essential characteristics of an LCA and good practices in conducing such a study (methodological framework, transparency requirements, measures applicable in case of transmission to third persons, etc.).

The four main steps of a life cycle analysis areas follows:

- The definition of the objective and scope of the study: ISO14041.
- The inventory of resource consumption and of emissions: ISO14041.
- The impact assessment of the life cycle: ISO14042.
- The interpretation of the life cycle's results: ISO14043.

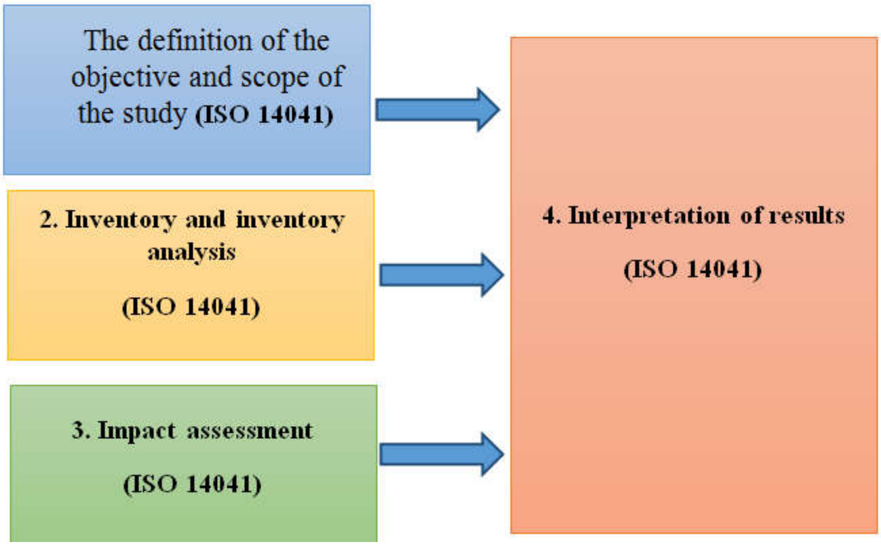

Figure 1. Interactions between the Life Cycle Analysis Steps (ADEME, 2005)

2. Method

2.1 Defining the Objective and the Scope of the Study

2.1.1 Defining the Objective

The aim of our study is to apply the LCA to the low-cost house in urban areas in order to measure the environmental impacts during the life cycle of our building. This will bed neon the basis of the LCA methodology that thoroughly assesses the impacts of a building using twelve environmental indicators:

i. Indicators on the consumption of:

- Energy;
- Water;
- Resources.

ii. The indicators of emissions into nature such as:

- Inert waste;
- Radioactive waste;
- GWP100;
- Cidification;
- Eutrophization;
- Co toxicity;
- Humantoxicity;
- O3-smog;
- Odours.

2.1.2 Defining the Scope

The scope with in which we shall carry out our study features the following items:

i. Function and related functional units

Functional units adopted to determine the value of the various indicators during the three phases of the building's life span:

- Internal usable surface: 93.7m^2;
- Internal usable volume of the building: 225m^3;
- Occupation: 6 persons;
- In-house services provided by house hold appliances and usual entertainment products such as the gas cooker, the refrigerator, the air-conditioner, the computer, the TV set and the radio;
- Water supply by CDE;
- Electricity: voltage provided 220 volts.

ii. Life span

It is supposed that construction works of our buildings train July 2016 and end in December 2016. Thus, our house is readyon 1st January 2017; the life span of our house is estimated at 50 years.

iii. Limits of the system

The limits define the scope with in which the system is studied. Al what fall without this framework is not taken into consideration. The system studied covers the construction, utilization maintenance and demolition of the building period and designed following a good number of well-established hypotheses. Figure 2 presents asketchyvie was well as the scope within which all the flows of materials and energy are listed for the life cycle of the building. This sketchy model of the life cycle is designed to include the astuteness of giving more importance to the nearest material supply points.

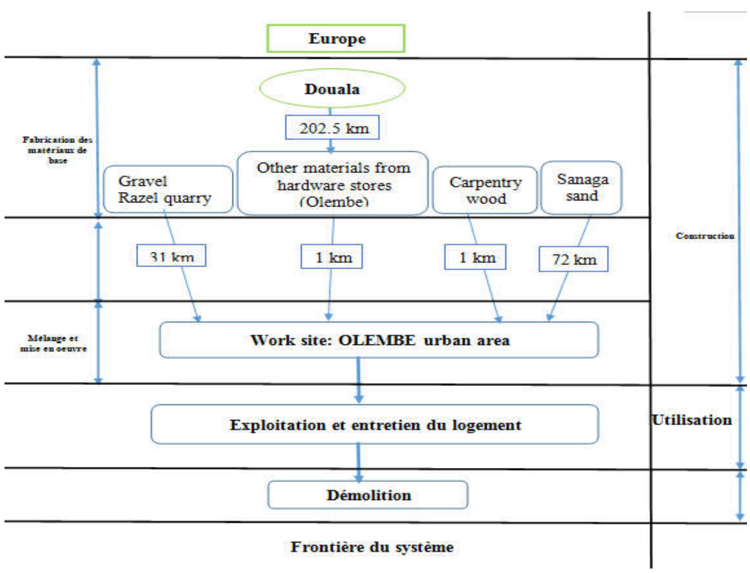

Figure 2. Sketch of the Building's Life Cycle

vi. Flow inventory

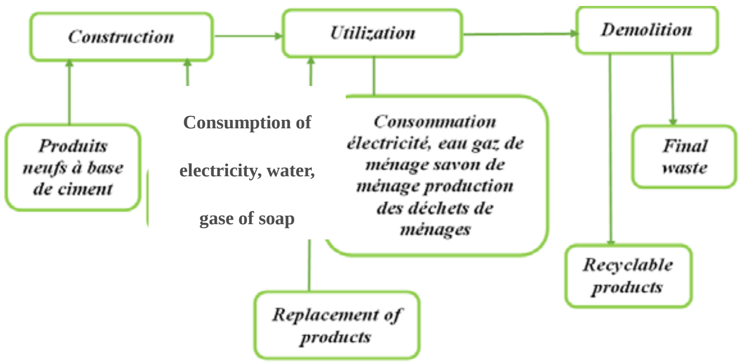

Figure 3. Principle for the Calculation of the Inventory

2.2 Presentation and Justifications of the Building

This is a single-storey low-cost house located in the Olembén eighbor hoodatal attitude of 3.9500° and alongitude of 11.533° in Yaoundé, whose characteristics are given in the Tables below, as well as the Distributionplan. Anestimate of the building is also attached.

Table 1. Civil Engineering Features of the Low-Cost Building

		Projet surface area	$120m^2$	
		Surface area used	$94\ m^2$	
		Internal volume	$225\ m^3$	
	Type of materials	Materials made with cement		
Various parts of the building	Structure of the building (inner net dimensions of these elements (1 to 7) represent the living area of the building)	1 living room	19 à$30m^2$ (27.76)	Paillassede (2.50 x 0.60) m² et 0.90mdehauteur
		Threebedrooms	10 à$13m^2$	
		1 kitchen	$7m^2$	
		1 bathroom	$3.5m^2$	
		1 toilet		
			$1m^2$	
		Passage way	Atmost 12% of the living area	
		1 drier/launde rette		
	Entry doors of the house		1.10m x 2.17m	
	French windows		1.04m x 2.17m-1.04m x 2.40m	
Dimension of doors and			1.20m x 2.17m-1.20m x 2.40m	
			1.40m x 2.17m-1.40m x 2.40m	

windows	Windows	0.80m x0.63m-1.20m x 1.60m
		0.90m x 1.40m-0.90m x 1.50m
		1.20m x 1.20m-1.20m x 1.40m
		0.85m x 2.10-0.95m x 2.10m
	Inner doors	0.70 m x 2.1m

Table 2. Electrical Features of the Low-Cost House

Various parts of the building	1 parlour	1 or 2 lighting spots (1DA + 1SA) or 1DA 2 or 3 sockets with ground connection (P + T) 1 collective TV antenna
	Bedrooms	1 lighting spot SA. 1 socket 1 collective antenna socket in the 2nd bedroom (for parents)
	1 kitchen	1 SA lighting spot on the ceiling 1 0.60 light tube with T-positive socket above the kitchen garden 2 sockets with ground connection (P+T) at 1.60m above ground level
	Toilet	1SA lighting spot

Table 3. Carpentry Equipment, Technical Andsewage Disposalducts of the House

Equipment	Description
Carpentry	Carpentry works must be done with good quality materials according to the rule book; measures for perfect adjustments and setting up must be respected to the letter. In any case, the choice of the type of materials must be justified technically (resistance, behavior, durableness, water-proofness, the rmalandacoustic performances) and financially. Entry doors of the houses must also obey to safety and anti-intrusion requirements by the type of materials used, the sealing method and the shutting system. Inshort, carpentry works must be carried out according to international rules and norms relatingto the type of the proposed carpentry works.
Technical ducts	Four technical ducts must be provided for and putin place according to norms inforce; they will host electrical installations for power, telephone and TV supply
Sewage disposal system	Separate plumbing piping must beprovided for wastes ewage, sewage water and rain water. They could end into a single main sewer, especially in the case of a combined system. Rain water will bedrained through appropriate piping; we should avoid direct draining over front walls or other method that could contribute to their rapid

	degradation.

Table 4. Estimates

WORKS DESCRIPTION	UNIT	QUANTITY
Work site installation		
Work site installation and clearing	FF	
Subtota l1.00		
Draining and disposal of rain water		
Putting in place of rein forced or prefabricated manholes	u	1
Subtotal 2.00		
Sanitation EU-EV		
Construction of man holes EU-EV	u	3
125PVC piping network	ml	1.5
Construction of water treatment and sanitation systems EU-EV (skeptical pits andsumps)	Ens	1
Subtotal 3.00		
Establishment-Foundations		
Pitexc avations	m^3	11.38
Trench excavations	m^3	29.5
Paved compacted back fills	m^3	25.16
Excavation back fills	m^3	4.84
Oversite concrete at a dosage of 150kg/m3	m^3	2.7
Concrete for pillar and long beams hoesata dosage of 300kg/m^3	m^3	3.5
Concrete blocks for basement wall	m^2	30
RC foundation wall tie at a dosage of 350kg/m^3	m^3	3
Subtotal 4.00		
Bricklaying		
Hollowconcrete blocks of 15x20x40	m^2	203
Reinforcedconcrete for pillars, lintels and upper wallties	m^3	11.5
Cement mortarcoating	m^2	405
Bush hammered cement topping	m^2	110
Flags tone paving at adosage of 300kg/m3 over a sandy bed	m^2	94
Subtotal5.00		
FRAMEWORK– ROOFING		
Wooden trusses 3*15	m^3	2
Wooden purlins (4*8)	m3	1.5

Roofingaluminum sheets 6/10	m²	99.69
Fascia boards protected with sheets of 7/10	m3	120
PVCrain water gutters, including hooks and others accessories	ml	19.81
Downspouts, including holders	ml	29.38
Dropped ceiling, including joisting	m²	110
Subtotal 6.00		
Carpentry-Wood		
Supply and installation of complete solid doors of de 0.85 x 2.10	U	7
Supplyand installation of complete thermal-reak door of		
of0.65 x 2.10	U	2
of0.02 x 0,6 x 2.10	U	1
Supply and installation of glass sash window frames	U	7
Supply and installation of complete cupboards, including all room implements (240 x 220)	U	4.69
Supply and installation under-counter cup boards	U	1
Subtotal 7.00		
Metaljoinery, NACO & glazing		
10 mm-Wrought ironsecurity grids	U	7
Pairs of 8-balde NACO sashes	U	8
Of 5blades	U	3
1.2 mclear NACO blade	U	66
Of 0.6m	U	19.06
Subtotal 8.00		
Electricity		
Straps	U	1
Distribution box	U	1
S.A.S witch	U	7
Three-way switches	U	7
Double S.A switches	U	7
Double three-way switches	U	7
Push buttons	U	7
Light tubes	U	15
Bulbs	U	6
Simple windows	U	3
Installation	FF	
Subtotal 9.00		

Plumbing		
Coldwater PVC pressure supply pipe 20/27	ml	16.88
Coldwater PVC pressure supply pipe 15/27	ml	26.25
Hotwater copper supply pipe	ml	18.13
PVCÆ63 waste pipe	ml	27.19
PVCÆ100 waste pipe	ml	11.25
Supply and install ation of a complete wash stand, including valves and fittings and emptying	U	2.81
Supply and installation of a WC low-end flushing tank accessories included	U	2.81
Supply and installation of a complete Bidet, including fittings and waste outlet	U	
Supply and installation of a ground bathroom floor drain included	U	2.44
Supply and installation of a stainless two-compartment sink including fittings and waste outlet	U	1
Supply and installation of a complete shower stack, including fittings and waste outlet	U	2.44
Supply and installation of a bathroom shelf	U	2.81
Supply and installation of asoap holder	U	2.81
Supply and installation of a toilet paper dispenser	U	2.81
Supply and installation of a 60x40 bathroom mirror	U	2.81
Supply and installation of a two-layer towelbar	U	2.44
Supply and installation of aground floor drain	U	2.44
Supply and installation of a single compartment laundry tub	U	1
Supply and installation of a faucet	U	1
Subtotal 10.00		
Wall facing and flooring		
Stone ware tiles for living room and dining room	m²	25
2X2 Stone ware tiles in toilet floorings and W.C	m²	9,38
Faïence tiles of 15X15 on toilet and W.C walls, and at 0.45cm above the sink of the kitchen's work top	m²	11,25
Subtotal11.00		
Paintings		
Vinyl pain to nouter walls, including all main spaces	m²	187,5
Vinyl paint on inner walls, ceilings and subfloors, including main spaces	m²	490,63
Glycerophtalic paint on wood works, metallicjoinery, kitchen and wash-uprooms and adjoining areas	m²	35,94
Cellulosiclacquer on all wood works and adjoining areas comprises	m²	4,53

Subtotal12.00	

2.3 Hypotheses and Elements of the Study

In order to apply the LCA on social lodging, we need to set down some hypotheses and we must have some elements.

2.3.1 Hypotheses

H1: General environmental impacts indicators obtained at the end of the building's life cycle are assessed following the steps described below.

Data presented, taking into consideration the extraction of the raw materials and the production of materials that are manufactured or not; then impacts resulting from the following processes are added:

- Transportation of manufactured parts to the building site;
- Energy and carbon dioxide produced during the manual phase of the use of the building's components;
- Impact indicators through hout the use of the building (lighting, specific electricity);
- Environmental impact of maintenance and improvement materials;
- Environmental impacts of the destruction of the house;
- However, it should be noted that the value of environmental impacts during the production of building materials (trucks, Wheel barrows, scoops, vibrators, etc.) were not taken into account.

H2: It is considered that environmental impacts of the building's components are constant over the time.

H3: Processes and factor excluded. Inade concentratedeff or to farchitectural systems that directly impact the use of energy and the overall heating potential of the low-cos thouse, some components of alow-cost house and some external factors were not listed. Belowisa list of some questions that were not included in the study:

- The location, since it deals with impacts on local ecosystems, personal questions on transportation, and urban issues on planning (including ewage and road infrastructures);
- The house surroundings (for instance foot path concrete, developments, draining);
- Furniture (kitchen and bathroom boxes, etc.);
- TV and telephone connections (external and internal systems, including wiring and firealarm);
- Behavioral models of inhabitants; this involves food consumption, leisure equipment, clothing, furniture, the supply of pet;
- animals, cleaning products or other articles that require no energy for the operation;
- Other environmental impacts happening in the whole life cycle;
- Environmental and social impacts related to the origin of building materials;
- Upcoming technological developments that significantly reduce energy consumption and the cost of house hold appliances;

H4: Materials supply sites remain the same through hout the life cycle.

H5: For an overall lappraisal of our building, it is supposed that the price of materials would slightly increase in the long run.

2.3 Hypotheses and Elements of the Study

2.3.1 Elements of the Study

We have established acorrelation between the HNPS and the EQUER software inorder to fill the indicator deficit of the HNPS. Of course, we carried out a compatibility operation on our various indicators so that our study should not be distorted.

1) Transportation of materials

- Supply of materials manufactured in Douala;
- Gravel supply site: Razel quarry situated at Nkometou.

Table 5. Transportation of Materials (ELIME, 2012)

Materials	Equipment	Energy consumed (MJ/t.km)	Distance (km)
Sand	20 ttruck	1.1	72
Gravel	20 ttruck	1.1	31
Hard ware store materials (cement, steel…)	16 ttruck	1.1	203.5

The power of the 16t truck remains equal to that of the 20t truck to take the vehicle's energy consumption in Cameroon into account, due to their age.

Table 6. Unit Power Consumption for the Production of Basic Constituents and Basic Tasks Needed for the Building (ELIME et al., 2009)

Designation	*Unitpower consumption*
Steel	26355.00MJ/t
PVC	9 240.00MJ/t
Cement	473.6MJ/t Lime 10164.00MJ/t Asphalt5 390.00MJ/t Geotextile96.56MJ/m2
Asphaltemulsion 60%	3 839.00MJ/t
Crushed aggregates	44.00MJ/t
Rolled aggregates	33.00MJ/t
Fuel	36.00MJ/t
Deforestation,cleaningand clearing offoftheland acquired	18.56KMJ/m2
Clearing of light materials	13.80MJ/m3
Clearing of rock materials	38.4MJ/m3

Storageofclearedmaterials	6.72MJ/m3
Compactingthebackfill	6.04MJ/m3
Transportationwithtrucks luMJ/txkmTransportation bysea 300.00MJ/tour Hotcoatingproductionstation 302.50MJ/t	
Lukeworm coatingproductionstation .40MJ/t Coldproductionstation(concrete) 15.40MJ/t Water station 10.00MJ/t	
Clearing of shoulders	1.6MJ/T
Platform reshaping over10cm	6.72MJ/m3
Reshaping withmixing	33.67MJ/m3
Reinforcedconcrete liningby m3ofconcrete	6.13MJ/m3
Reinforcement 3.25MJ/T Steeltubeguardrails 253.5MJ/ml Geotextileworks 3.12MJ/m2	
Constructionofguardrails	6.05MJ/Mml

Table 7. Powersource

		MJ of production		
Energy(MJ)	MJ	1.299	1.558	36
Water	kg	0.02481	0.1036	6.032052117
Resources	10^{-09}	7.7E-18	4.389E-16	8.94723E-15
Waste	Teq	0.0058	0.006819	0.105302932
Radioactivewaste	dm^3	0.000000034	0.00000052	0.000140717
GWP100	kgC02	0.00117	0.08395	2.352312704
Acidification	kgS02	0.000006	0.000099	0.005159609
Eutrophization	$kgPO_4^{3-}$	0.000000058	0.000011	0.000328339
Ecotoxicity	m^3	0.04933	0.3737	67.89576547
Human toxicity	kg	7.686	0.00013	0.007035831
03-smog	kg	0.0000036	0.000084	0.004221498
Odours	m^3	7.686	159.3	463.8957655

Table 8. Basics Constituent’s Indicators

Indicators	Unit	Reinforcementsteel(T)	Galvanized steelsheets (T)	PVC(T)	Cement(T)	Lime(T)	Sand(T)	Crushed aggregates (T)	Rolled aggregates (T)	Transportation pertonperkm (T)	Water station (T)	Woodfor development (T)	Irondoor (T)	Tilings(T)	Paint(T)
Energy(MJ)	MJ	26355.000	70380.000	9240.0	5473.600	10164.00	33.000	44.000	33.000	1.100	10.000	6545.000	1.7E+05	8110.000	24089.400
Water	kg	15537.600	3.4E+05	6584.2	3263.180	7463.220	18.453	91.845	23.690	0.487	389.575	664.950	1.0E+05	3100.000	20746.800
Resources	10^{-09}	3.69E-12	4.26E-10	0.0	9.30E-13	3.22E-12	5.00E+00	2.56E-14	9.38E-15	4.33E-16	6.72E-15	2.18E-13	2.41E-13	2.24E-12	3.07E-10
Waste	Teq	0.972	1.301	0.0	2.544	0.000	1392.830	0.192	0.000	0.034	0.003	29.150	2979.900	190.000	110.700

Radioactive waste	dm^3	0.030	0.041	0.0	0.008	0.0E+00	0.064	0.001	0.0E+00	4.1E-06	3.2E-05	0.007	0.126	0.047	0.046
GWP100	kgC02	1277.370	3880.000	273.6	955.506	1216.979	1.857	8.086	1.788	0.067	0.003	-455.217	8421.233	360.000	675.000
Acidification	kgS02	3.242	20.890	2.0	2.361	3.141	0.006	0.028	0.021	0.001	0.000	0.079	21.047	1.000	4.320
Eutrophization	$kgPO_4^{3-}$	0.341	1.359	0.1	0.279	0.362	0.001	0.005	0.003	0.000	0.000	0.013	2.233	0.140	0.221
Ecotoxicity	m^3	0.166	3.3E+05	14895.3	0.014	17859.96	0.000	0.000	54.417	2.191	0.675	0.001	1.078	0.003	19134.900
Human toxicity	kg	46.232	53.200	3.1	6.385	4.059	0.014	0.063	0.026	0.001	0.045	0.770	191.730	2.100	17.820
0_3-smog	kg	0.419	8.258	0.8	0.102	2.632	0.002	0.009	0.021	0.001	0.000	0.018	2.823	0.071	1.512
Odors	m^3	0.000	6.6E+07	3.9E+05	0.000	1.7E+06	0.000	0.000	3128.850	77082.000	28.996	0.00E+00	7.70E-04	0.00E+00	1.8E+06

Table 9. Summary of Building Indicators of Mixing for 1m³

DV		Indicators related to production	Indicators related to production	Indicators related to production	Indicators related to production	Indicators related to production
	MJ	1744.073	1735.388	1768.127	3105. 06208	950.337
Water	Kg	1082.559041	1070.513065	1170.982885	1972.623717	664.292142
Resources	10^{-09}	9.607245283	8.981773585	4.128113206	4.003018868	4.553433962
Waste	Teq	2674.997715	2500.893867	1150.1001014	1115.455297	4.553433962
Radioactive waste	dm^3	0.12554079	0.117521114	0.055979418	0.056016007	0.060273789
GWP100	kgCO2	292.8515671	292.4544076	301.6139902	401.2517281	158.767475
Acidification	$kgSO_2$	0.720745445	0.719942734	0.749917848	0.99953794	0.397631405
Eutrophization	$kgPO_4^{3-}$	0.086000569	0.085859004	0.090972114	0.118866464	0.049391979
Ecotoxicity	m^3	0.122308268	0.105426045	0.10239312	0.126577522	0.059756299
Human toxicity	m^3	1.950416141	1.947527583	2.016359405	4.198039263	1.06033054
O3-smog	kg	0.034615889	0.034356165	0.043757584	0.066092981	0.029054502
Odors	m^3	5.07431939	4.34941664	4.204436107	4.929343145	2.464669438

Table 10. Building Processes Given by the 2008 HNSP

Work siteprocess	Unit	Energy
Loosematerials	MJ/3	13.8
Cold production site (concrete)	MJ/t	15.4
3	3	6.13
Reinforced concrete formwork by mof concrete	MJ/m	
Reinforcement	MJ/t	3.25

Table 11. Energetical Formulas

Symbol	*Name*	*Formulas*
EaEnergy spent for physical activity perhour	ET=*GW * T*NEO	Energy during in active period and perhour
GWP100	CO2 releases by an individual per hour and in terms of physical activity	
GWP0	CO2 released by an idle person and per hour	
T	working time in hours	
N	Number of persons carrying out a given task	

Table 12. Energy and GWP100 Indicators for Some Work Site Processes

Worksite process	*Unit*	*Energy per Person (kcal)*	*Number of persons*	*Working time (H)*	*Energy in MJ*	*CO2 released in kg*
Trenching of soft soil laid at 20m	3 m	400	2	4.1	13.8	0.83350588
Cold production station (concrete)	t	400	2	4.6	15.4	0.93515294
Reinforced concrete lining per m^3 of concrete	m^3	275	2	2.67	6.13	0.37037647

Table 13. Energy for the Manual Use of Project's Materials

Mortar for coating	*Unit*	*Number of persons*	*Time in Hours*	*Energy (Kcal) per person and per hour*	*Overall energy (MJ)*
	M^3	1	24	120	12.0384
Chipboards	T	1	5	140	2.926
Wood and framework	m^3	2	16	140	18.7264

Energy for the use of some building materials with in the framework of the project

	Unit	*Number of persons*	*Time in Hours)*	*Energy (Kcal) per Person and perhour*	*Energy (MJ/m^2)*	*Thickness (mm)*	*Overall energy (MJ)*
Roofing	m^2	2	0.2	150	0.2508	0.3	836
Paint	m^2	1	0.15	130	0.08151	0.3	271.7
Doors	m^2	1	0.1	135	0.05643	30	1.881
WC/toilet tiles	m^2	1	0.6	100	0.2508	4	62.7

Table 14. Complementary Data Perkg of Constitutive Material

Indicator	*Unit*	*Adobe*	*Raw compressed earth blocks*	*Cinderblock (dosage 300kg/m³)*
AR	MJ	0.002745	0.002521	0.76506
Water	kg	0.00015	5.89E-05	0.46544
Resources	10^{-09}	0	0	0.00391
Waste	Teq	0	0	1.08735
Radioactivewaste	dm³	0	0	0.00005
GWP100	Kg C02	0.04565	0.042	0.12764
Acidification	Kg S02	0	0	0.00031
Eutrophization	Kg PO_4^{3-}	0	0	0.00004
Ecotoxicity	m³	0	0	0.00005 Given:
Human toxicity	kg	0	0	0.00085 ***E***: raw materials extraction indicator; ***F***: indicator for the production
O3-smog	kg	0	0	0.00001
Odours	m³	0	0	0.00189

Table 15. Some Features of the Two Buildings

Designatio	*Urbanarea*
Water supply	CDE
Lighting and household equipment power supply	Electricity
Plumbing equipment	Complete
Equipment network for power use	Finished electrical
waste liquid solliquid solid	Septic tanks
	HYSACAMcompan

3. Result

Given: **E**: raw materials extraction indicator; **F**: indicator for the production of materials; **T**: transportation indicator; and finally, **M**: indicator for the putting in place of the building site: being the environnemental impact indicator. We have therefore: **I = E+F+M+T**

Table 16. Environmental Impact Indicators during Construction Phase

Indicator	Unit	Cleaning concrete
Mortar	Concrete blocks	
Concrete	Reinforced concrete	
Framework	Alu ironsheets	Woodenddoorand windowframes
Irondoor	Tiles	Paint OTAL

Energy MJ 5126.612 10173.0195 13883.1784 18505.4889 19866.4081 60192.6236 49.1610806 115.502852 2415.105 21.9779478 4840.251 135189.328

Water kg 3103.001 6071.18166 8841.67966 11864.8294 12356.1092 6106.79624 21.94172 11.7392042 1418.004 8.62985595 4168.60435 53972.5163

Resources 10^{-09} 9.4337E-13 1.9354E-12 2.7991E-12 3.6787E-12 3.5474E-12 2.001E-12 1.9295E-14 3.8935E-15 3.3558E-15 7.68E-15 6.1683E-11 7.6622E-11

Waste Teq7220445.677007 13772341.6 8043643.98 10916365.1 6685626.38 267.738675 1.56159122 0.51650882 41.4477 0.56790116 22.242902 46638756.8

*Radioactive*dm³ 0.34047644 0.65070569 0.39726874 0.5380221 0.34046447 0.06566129 0.00021607 0.00012603 0.0017493 7.3134E-05 0.0092226 2.34398586

GWP100 kgC02 814.925 1575.39481 2198.37311 2964.9696 2477.6091 -4179.53126 2.95768187 -7.96608246 117.1317 1.18603122 135.626498 6100.67545

Acidification kgS02 2.217 4.45659223 6.21599842 8.23451138 6.77730458 0.72584867 0.03142082 0.00150981 0.29274 0.01278235 0.86801181 29.8335023

*Eutrophization*kgPO_4^{3-} 0.27552467 0.56206344 0.79145656 1.04188178 0.83801109 0.12152245 0.00501987 0.00025185 0.031059 0.00204443 0.04448619 3.71332133

Ecotoxicity m³ 818.054337 2249.78451 2919.76822 3354.05343 2356.59181 6.09237596 94.4126156 0.38724589 0.014994 38.4893754 3844.74218 15682.3911

Human kg 5.60187785 10.9681371 15.313067 20.5321762 26.155531 7.07249902 0.03933776 0.0136536 2.66679 0.01588238 3.58053311 91.9594849

O3-smog kg 0.38589404 0.98260527 1.35020245 1.61481222 1.23904098 0.16714323 0.03378227 0.00045336 0.03927 0.01376708 0.30380808 6.13077897

*Odours*m³ 28801.9215 79208.2915 102795.524 118086.169 82967.3557 214.270567 3323.82423 13.6326997 0.00001071 1355.02993 366950.281 783716.299

Table 17. Environmental Impact Indicators during the Exploitation Phase

Energy	MJ	1.299	279936	363636.9	10	4320	43200	0.0143	1003.97	600	602393.7	0.605	357	2.9988	1072.3859	1010302.95
Water	kg	0.02481		6945.212	389.5749		1682963.6	0.006301	66.75984		40059.685	0.266583	36.27		109.56591	1730078.031
Resources	10^{-09}	7.7E-18		2.16E-12	6.72E-15		2.902E-11	5.62E-18	2.83E-13		1.697E-10	2.38E-16	1.19E-14		3.634E-14	2E-10
Waste	Teq	0.0058		1623.629	0.002973		12.84323	0.000415	4.394164		2636.7472	0.017559	1.59		4.820749	4278.039963
Radioactivewaste	dm³			3.4E-08				0.009518	3.24E-05				0.1397744		5.28E-08	0.000335

0.2010845	2.23E-06	0.00039			0.0011762	0.351552929						
GWP100	kgC02	0.0011	327.52	0.003359	14.511182	0.000868	54.097	32458.949	0.036715	-24.83	-74.3501	32726.634
Acidification	kgS02	6E-06	1.679616	3.29E-05	0.1422763	9.43E-06	0.063796	38.28302	0.000399	0.0043	0.0140916	40.11900353
Eutrophization	$kgPO_4^{3-}$	5.8E-08	0.016236	2.19E-06	0.009474	1.51E-06	0.007088	4.2539455	6.39E-05	0.00072	0.0023506	4.282006412
Ecotoxicity	m^3	0.04933	13809.24	0.675289	2917.248	0.028487	240.8123	144504.46	1.205211	0.000036	3.6142949	161234.5653
Humantoxicity	kg	7.686	2151588	0.044788	193.48243	1.17E-05	0.083772	50.270218	0.000495	0.042	0.1274336	2151831.976
O3-smog	kg	3.6E-06	1.00777	1.16E-05	0.0502054	1.02E-05	0.05413	32.483872	0.000431	0.00098	0.0042313	33.54607867
Odours	m^3	7.686	2151588	28.9961	125263	1.00288	102652	61592354	42.42982	0	127.2385	63869332

Table 18. Environmental Impact Indicators during the Maintenance Phase

Indicator	*Unit*	*Wall (bricklaying and coating)*	*Paint*	*Sheets roofing*	*forWooden door*	*Iron door*	*Floor covering*	*Toilet and WC equipment*	*Total*
Power	MJ	2672.91088	43562.259	49.1610806	269.506654	1610.07	4675.07088	73.7726449	52912.7511
Water	kg	1656.98459	37517.4391	21.94172	27.3914764	945.336	2997.43059	27.3278772	43193.8514
Resources	10^{-0}	5.2606E-13	5.5514E-10	1.9295E-14	9.0848E-15	2.2372E-15	9.2936E-13	2.432E-14	5.5665E-10
Waste	Teq	2423998.4	200.186118	1.56159122	1.20518726	27.6318	2757818.55	1.79835366	5182049.33
Radioactivewaste	dm^3	0.1164416	0.08300338	0.00021607	0.00029406	0.0011662	0.13592137	0.00023159	0.33727429
GWP100	kgC	419.307547	1220.63848	2.95768187	-18.5875257	78.0878	749.044952	3.75576552	2455.2047
Acidification	kgS	1.18584341	7.81210627	0.03142082	0.0035229	0.19516	2.08029761	0.04047743	11.3488284
Eutrophization	KgP	0.15039111	0.40037574	0.00501987	0.00058765	0.020706	0.26321224	0.00647401	0.84676662
Ecotoxicity	m^3	574.394748	34602.6796	94.4126156	0.90357374	0.009996	847.339813	121.883022	36241.6234
Human toxicity	kg	2.92013378	32.224798	0.03933776	0.03185839	1.77786	5.18707609	0.05029419	42.2313582
O3-smog	kg	0.25920086	2.73427273	0.03378227	0.00105783	0.02618	0.40795256	0.04359574	3.50604198
Odours	m^3	20222.6461	3302552.53	3323.82423	31.8096325	0.00000714	29832.2952	4290.92811	3360254.03

Table 19. Impact Indicators during the Destruction Phase

		Excavator for destruction		*Truck for transportation*		*Overall destruction Indicator*
Indicator	*Unit*	*Indicator bytonsof aggregatesTransportationintonsper kmQuantityo faggre gates to transport intonsDistance(km)*				
Power	MJ	16	1.1	97	5	2085.5
Water	kg	7.050131926	0.48469657			683.8628
Resources	10^{-09}	6.29024E-15	4.32454E-16			6.102E-13
Waste	Teq	0.464379947	0.031926121			45.044855
Radioactivewaste	dm^3	5.910E-05	4.062E-06			0.00573
GWP100	$kgC0_2$	0.970976	0.0667517			94.1846
Acidification	$kgS0_2$	0.01055	0.0007255			1.0237
Eutrophization	$kgPO_4^3$	0.001688	0.000116			0.16379

Table 20. Summary of Environmental Impacts of the Various Phases of the Life Cycle of Theurban L.C. H.

	Unit	*Construction*	*Exploitation*	*Maintenance*	*Destruction*	*Total*
Water	kg	53972.5163	1730078.03	43193.8514	918.940633	1828163.34
Resources	10^{-09}	7.6622E-11	2.0091E-10	5.5665E-10	8.1989E-13	8.3501E-10
Waste	Teq	46638756.8	4278.03996	5182049.33	60.5290237	51825144.7
Radioactivewaste	dm^3	2.34398586	0.35155293	0.33727429	0.00770369	3.04051677
GWP100	$kgC0_2$	6100.67545	32726.6349	2455.2047	126.560686	41409.0757
Acidification	$kgS0_2$	29.8335023	40.1190035	11.3488284	1.37565963	82.6769939
Eutrophization	$kgPO_4^{3-}$	3.71332133	4.28200641	0.84676662	0.22010554	9.0621999
Ecotoxicity	m^3	15682.3911	161234.565	36241.6234	4154.49208	217313.072
Humantoxicity	kg	91.9594849	2151831.98	42.2313582	1.70581794	2151967.87
O3-smog	kg	6.13077897	33.5460787	3.50604198	1.4857124	44.668612
Odors	m^3	783716.299	63869332.3	3360254.03	146260.132	68159562.7

The diagram above shows that the exploitation phase is the most important for all indicators, except for two indicators: waste and radio active waste. This situation is due to the fact that liquid and solid wastes produced by users are not taken into account. Thus, the set wo indicators are two outlier points of the study.

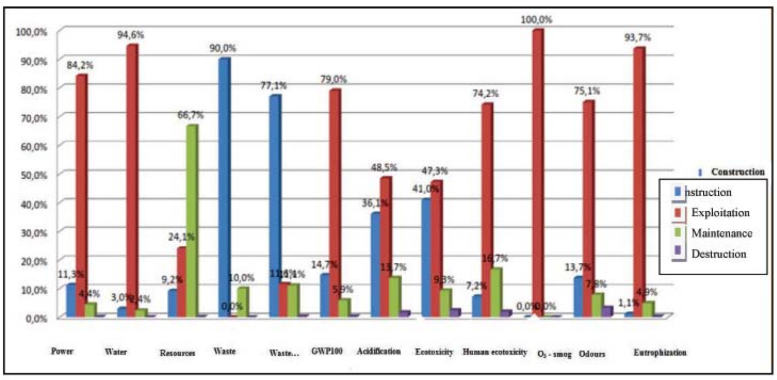

Figure 4. Impact Indicators of Urban Low-Cost Housing

Of the twelve indicators under study, two have the most exploited results of the study with in the frame work of LCA applied to the building. These are power and overall heating potential (**GWP_{100}**). The power indicator mainly deals with:

- Any power taken from nature to produce building materials;
- The production of power such as electricity. House holdgas (grey power);

- Exploitation power (electricity AES-SONEL);
- Production power and power used to pump water into houses.

3.1 Flow Assessment

Table 21. Water and Electricity Consumption

	Unit	Number of persons	Daily consumption per inhabitant	Monthly consumption of the household	Maintenance
Electricity	KWH	6	0.5944	107	0
Water	m³	6	0.06	10.8	780

Table 22. Cooking Gas and Soap Consumption

	Unit	*Number of persons*	*Monthly consumption of the household*
Domestic gas	L	6	26.5
Household soap	300g cube	6	12

Table 23. Use of the Urban House

Electrical bulb	8	1.16	43.10344
Electric install ation repairs electric	1	20	1.5
Wooden furniture	1	25	2
Wooden bed for bedroom	3	15	3.34
Cop board repairs	4	15	2.34

Table 24. Maintenance of the Social House

State employee Number or quantity	Usage duration	Frequency of replacement
Walls	45	0.11
Inner paintings	5	9
Outer paintings	5 9 Roos 25	1
Emptying the septic tank	7	6.15
Plumbing rehabilitation	5	9
Equipping of toilets	10	4
Floor covering	25	1
Windows repairs	7 35	0.42
Wooden doors	5 25	1

Iron outer door	35	0.42

4. Rsult Analysis

4.1 Impact Study

Here is the list of the twelve environmental impact indicators of the two houses according their various life cycle phases. Of the twelve environmental impact indicator sex amined, it appears that:

- The destruction phase is the one that has the smallest number of environmental impacts while the exploitati on phase has the higher number (9/12) and the most important ones. This could be explained by the high speed and the precision with which destruction is generally carried out; conversely, exploitation takes more time.
- For the water consumption indicator, the urban house has a high consumption rate. This is due to the fact that water supply.
- intown(CDE) is done with many losses.
- For consumption indicators of: *Waste. Radio active waste and odours*. the construction phase features the highest numberofindicators.

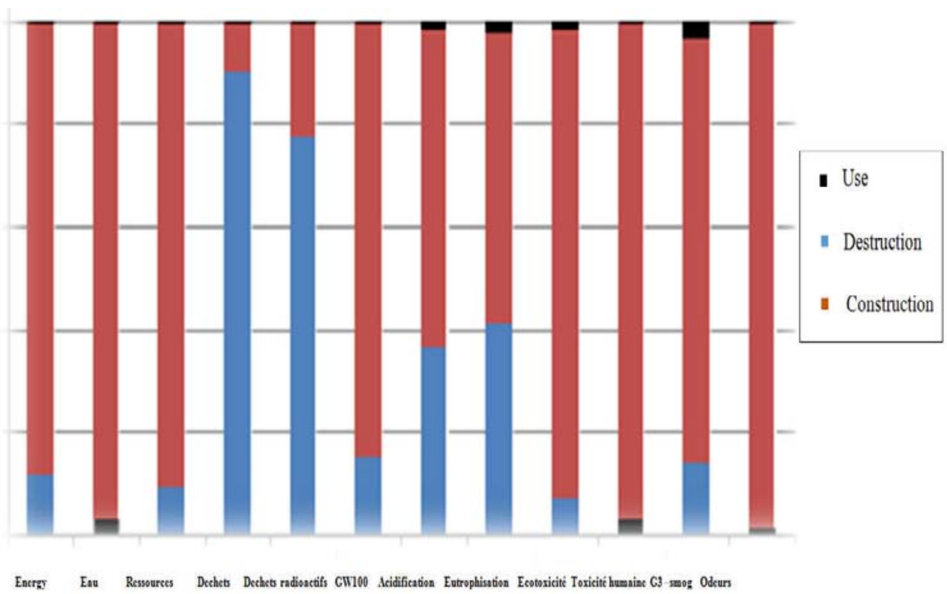

Figure 5. Share of Impacts for Various Phases of Urban Low-Cost Housing

4.2 Balance Sheet and Interpretation of the Life Cycle of LCH

The results of the LCA of the building constructedup till now apply to all environmental aspects: raw materials and power consumption; waste; green house-effect gas; acidification; eutrophization; Ecotoxicity; human ecotoxicity and odours; power consumption; impacton the climatic change called GWP100 are impacts that could be well directly appraised by users of the buildings.

Of the twelve indicators, except the two on waste (because waste produced by users of the building were not taken into account); the contribution of the use phase (exploitation and maintenance) of the building is very pre occupying as illustrated by the following Table.

Table 25. Percentage of Environmental Impacts of Variousphases of the Buildings' Life Cycle

	Utilization	Construction	Destruction
Urban house	86%	13%	1%

5. Conclusion

At the end of our study, the issue was applying life cycle analysis (LCA) to a **"T4 single-storey"** urban low-cost house. To that end, we had a data base setup by the HNPSP in 2008; using the data base from Switzerland. We completed the data missing in the 2008 HNPS database. On the basis of these data, we applied the LCA to a low-cost house and to that effect. We used the twelve impact indicators for acomplete implementation of the LCA.

The methodology used for the LCA of our building involved quantifying materials and components, and then the substances taken and released from and into the environment, taking into consideration invent or iesmainly provided by the 2008 HNPS database, the ECOINVENT data base from the EQUER software and field analyses. Results provided by our sample low-cost house reveal that the basis of utilization (exploitation and maintenance) is the most preoccupying at the level of environmental impacts, which reach their highest point during this phase and represent 86% of the life cycle's overall limpacts.

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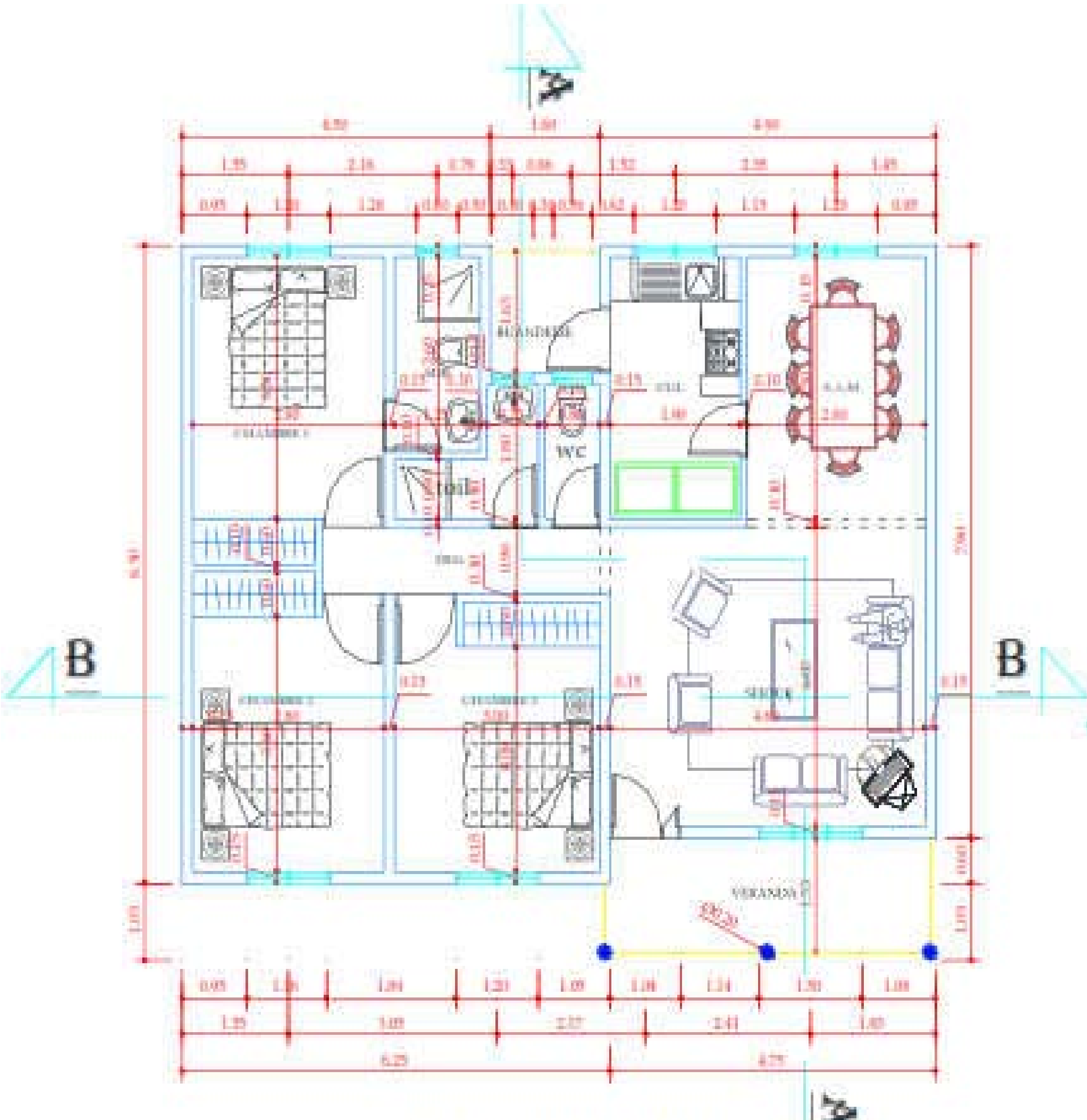
Appendix

Architectural Aspect: themodel chosen is of type T4



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